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Epidemiological Considerations of Concussions Among Intercollegiate Athletes

Tracey Covassin, C. Buz Swanik, and Michael L. Sachs

Department of Kinesiology, Temple University, Philadelphia, Pennsylvania, USA

The purpose of this study was to examine epidemiological trends of concussions among 15 different intercollegiate sports during the 1997–1998, 1998–1999, and 1999–2000 seasons. Data were collected using the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS). For the 15 sports studied during the 3 academic years, the NCAA ISS documented 3,535 team-seasons, 40,547 reportable injuries, 5,566,924 practice athlete exposures (AEs), and 1,090,298 game AEs. Concussions accounted for 6.2% of all reported injuries during this 3-year study. Of all the reported injuries, women lacrosse players (13.9%) reported the highest percentage of suffering a concussion during a game followed by women's soccer (11.4%), men's ice hockey (10.3%), men's lacrosse (10.1%), football (8.8%), women's basketball, (8.5%), field hockey (7.2%), men's soccer (7.0%), wrestling (6.6%), men's basketball (5.0%), baseball (4.2%), and women's volleyball (4.1%). Female athletes from all 7 sports were found to be at a lower risk for suffering concussions during practice sessions than the 8 male sports. However, female athletes were found to be at a greater risk for suffering concussions during games compared to male athletes. Injury trends over the 3-year period indicate concussions continue to be on the rise for athletes participating in collegiate football, men's soccer, and women's and men's basketball.

Key Words: concussions, intercollegiate sports, male sports, female sports, National Collegiate Athletic Association, Injury Surveillance System, injury, athlete exposure, injury rate, incidence density ratio

In recent years there has been increasing interest in the effects and evaluation of concussions in sports. There are approximately 300,000 sport-related concussions reported each year (Thurman & Guerrero, 1999). Most sports, especially contact sports, have an inherent risk of injury to the brain. Although many concussions are considered minor, the cumulative effects of repeated concussions can have long-term consequences (Evans, 1994; Kelly, 1995). Furthermore, athletic trainers and team physicians have difficulty detecting and fully characterizing sport concussions on routine clinical examinations because the athletes' motivation to participate in athletics may cause them to minimize their symptoms so they can continue to participate (Evans, 1994; Kelly, 1995).

Requests for reprints should be sent to C. Buz Swanik, Department of Kinesiology, Temple University, Pearson Hall #127, Philadelphia, PA 19122, USA.

Since injury trends in concussions are important for the health and welfare of athletes and their treatment, there is a need to determine which athletes have a more inherent risk of suffering a concussion. Moreover, there is a need to determine if athletes have an increased risk of suffering a concussion during practice sessions or games. Determination of concussion risk is also important for future advances by the National Collegiate Athletic Association (NCAA) Committee on Competitive Safeguards and Medical Aspects of Sports so they can make changes as needed. However, it is difficult to determine the true risk of concussions and the number of concussions in athletes, which may potentially be related to how the profession defines concussions. The sports medicine community does not know for certain how concussions resolve or the wide nature of individual symptoms that are encountered in concussed athletes. Neuropsychologists are in a unique position to assist in the assessment, diagnosis, and management of sports-related concussions. It is impor-

tant for neuropsychologists practicing in this area to understand the epidemiological nuances among the different sports and trends over time. As neuropsychologists become increasingly informed about the complex culture of intercollegiate sports and specific base rates of concussion, the more effective they will be in becoming an important resource in this field.

Essentially, there is no universal agreement on the definition of concussion. The historical definition refers to its Latin origin, *concutere,* meaning "agitation or shaking" of the brain (Maroon et al., 2000). The American Medical Association and the Committee of Head Injury Nomenclature of the Congress of Neurological Surgeons (1966) defined *concussion* as a clinical syndrome characterized by the immediate and transient posttraumatic impairment of neurological function (such as alteration of consciousness, disturbance of vision and equilibrium), due to brainstem involvement. The Quality Standards Subcommittee of the American Academy of Neurology (AAN; 1997) described cerebral concussions as an altered mental state that may or may not include loss of consciousness. This committee agreed that the most prominent symptoms of concussions are amnesia and confusion (see also Echemendia & Cantu, this issue).

Research on three sports, including football, ice hockey, and soccer, is summarized in this article. These three sports represent different areas on which research attention has focused and thus a review of previous epidemiological data is offered here.

Concussions in Football Players

Until the 1980s, there was very little research being conducted on concussions. Gerberich, Priest, Boen, Straub, and Maxwell (1983) reported one of the first studies regarding incidence and severity of concussions in high school players. The researchers surveyed 103 secondary football teams in Minnesota during the 1977 football season. The authors concluded concussions accounted for 24% of all football injuries. However, this study was conducted 3 years prior to implementation of the rule mandating that all football helmets be required to meet approval by the National Operating Committee for Safety in Athletic Equipment. As a result of the helmet rule, concussion rates have dropped considerably, to approximately 5% (Barth et al., 1989; McCrea, Kelly, Kluge, Ackley, & Randolph, 1997; McCrea et al., 1998). Several other researchers have studied concussions in high school and college football players. Buckley (1988) examined 35,879 college football players between the 1975 to 1982 seasons. The researcher concluded that 5.3% of football players sustained a minor concussion with less than 7 days lost from participation. McCrea et al. (1997) examined 141 Iowa high school football players during the 1995 football season. Six athletes suffered a Grade 2 concussion, which accounted for 4.3% of all football injuries.

Due to a high percentage of football players suffering concussions, the Quality Standards Committee of the AAN recommended the development of the Standardized Assessment of Concussions (SAC). The SAC provides immediate sideline neurocognitive impairment assessment of athletes who have just sustained a concussion (McCrea et al., 1998). The SAC was developed to aid in sideline evaluation for certified athletic trainers and physicians and is similar to a mental status evaluation; however, it does not replace a comprehensive neuropsychological test battery. McCrea et al. (1998) administered the SAC to 568 nonconcussed high school and college football players prior to the start of the season. Thirty-three athletes (5.8%) suffered a concussion during the season. They scored significantly below their own preinjury baseline score on the SAC. Similar results were reported by Barth et al. (1989), who indicated that 7.7% of all football players sustained a mild head injury during the season.

Very few studies have been published on professional football players. Delaney, Lacroix, Leclerc, and Johnson (2000) investigated the incidence and characteristics of concussions in professional football players in the Canadian Football League (CFL). All players completed a questionnaire about concussions they sustained during the 1997 CFL season. Players self-reported their signs and symptoms and the duration they were unable to play football. Results indicated that 8.4% recognized they had sustained a concussion during the season. However, 44.8% of players reported signs and symptoms of sustaining a concussion. The most common clinical symptoms of concussion were confusion, followed by headache, dizziness, and blurred vision. Results revealed that 69.6% of football players who experienced signs and symptoms of concussion reported more than one episode during the 1997 season.

If an athlete is experiencing postconcussion symptoms and returns to play prematurely, this may lead to catastrophic consequences (Cantu, 1996; Fekete, 1968; Kelly et al., 1991; McCrory & Berkovic, 1998; Saunders & Harbaugh, 1984). Second-impact syndrome occurs when an athlete sustains a second head injury while still recovering from the first head injury

(Cantu & Voy, 1995). Therefore, better tracking of concussions using neuropsychological procedures may help minimize the risk of second-impact syndrome and potential neuropsychological impairments.

Concussions in Ice Hockey Players

Ice hockey has recently had several prominent professional hockey players who were diagnosed with concussions or forced to retire due to numerous concussions. As a result, the National Hockey League (NHL) formed a committee to examine this increased incidence of concussions in hockey players. Tegner and Lorentzon (1996) examined the frequency of concussions among Swedish elite hockey players. The participants of the study represented 12 teams, with 628 games played and a total of 7,536 player-game-hours. Doctors diagnosed 52 concussions during the four ice hockey seasons (5%). The authors concluded that around 20% of all elite ice hockey players will sustain at least one concussion during their entire hockey career. Lorentzon, Wedren, and Pietila (1988) reported Swedish elite hockey players had a 5.3% risk of sustaining a concussion during a hockey season.

Concussions in Soccer Players

Several researchers have shown interest with regards to the prevalence and incidence of concussions among soccer players. Concussions have been reported to constitute 2% to 22% of all soccer injuries (Barnes et al., 1998; Boden, Kirkendall, & Garrett, 1998; Bruce, Schut, & Sutton, 1982; see also Webbe & Ochs, this issue). Boden et al. (1998) examined the mechanism and incidence of concussions in male and female varsity soccer players participating in the Atlantic Coast Conference. Results indicated that the concussion incidence for men was 0.6 per 1,000 athlete exposures (AEs) and 0.4 per 1,000 AEs for women over the two seasons studied. This supports Barnes et al.'s (1998) research, which concluded that men have a higher incidence of concussions than women and concussions are becoming more common than previously anticipated.

No studies to date have examined epidemiological injury trends over time on collegiate athletes who sustain a concussion. Therefore, the purpose of this study was to examine the incidence and prevalence of concussions among 15 different intercollegiate sports during the 1997–1998 to 1999–2000 seasons. A secondary goal of this study was to determine which sports are associated with a greater risk of suffering a concussion during games versus practice sessions.

Methods

Data were collected using the NCAA Injury Surveillance System (ISS) from 3,535 team-seasons. Certified athletic trainers from participating NCAA institutions recorded injury and AE data from the first day of preseason practice to the final postseason game. Data collected from each sports season (fall, winter, spring) were then summarized and reviewed by the NCAA Committee on Competitive Safeguards and Medical Aspects of Sports. The NCAA ISS was developed in 1982 to provide reliable and current data on injuries sustained by intercollegiate athletes (NCAA, 1997). During the 1982–1983 academic year, injury data were collected on football players only. By the 1999–2000 academic year, the NCAA ISS had expanded to 15 sports, including 5 fall sports (field hockey, football, men's soccer, women's soccer, and women's volleyball), 6 winter sports (men's basketball, women's basketball, men's gymnastics, women's gymnastics, men's ice hockey, and men's wrestling), and 5 spring sports (baseball, men's lacrosse, women's lacrosse, spring football, and softball).

Sampling

Participation in the NCAA ISS system was voluntary. Selection to participate in the ISS was random, but there is a minimum of 10% representation from each region (East, South, Midwest, and West) and NCAA division (I, II, and III). Therefore, NCAA ISS collected a random sample that is representative of a true cross section of NCAA institutions.

Terminology

The following terminology is used in this article:

- *National Collegiate Athletic Association (NCAA).* The NCAA acts as a governing body to establish rules and regulations in United States collegiate sports to provide for safer and fairer sports participation.
- *Injury Surveillance System (ISS).* The ISS collects yearly injury data from a representative sample of NCAA institutions.

- *Injury.* The ISS defined a reportable injury as one that occurs as a result of participation in an organized intercollegiate practice or game, requires medical attention by a team athletic trainer or physician, and results in restriction of the student-athlete's participation for one or more days beyond the day of injury.
- *Athlete Exposure (AE).* An AE is defined by the NCAA ISS as an athlete participating in one practice or game where she or he is exposed to the possibility of athletic injury. Certified athletic trainers submit a weekly exposure form, summarizing the number of practices and games. For example, four practices, each involving 15 participants, and two games involving 9 participants, would result in 60 practice AEs, 18 game AEs, and 78 total AEs for that week.
- *Injury Rate.* The NCAA ISS defines an injury rate as the ratio of the number of injuries in a sport to the number of athletes exposed to the same sport. Injury-rate values are expressed as injuries per 1,000 AEs.
- *Incidence Density Ratio (IDR).* The IDR is an estimate of the relative risk based on injury rates per 1,000 AEs. The IDR is a ratio comparing games to practice injury rates of athletes sustaining a concussion. It is calculated by dividing the injury rate of games by the injury rate of practice sessions. The IDR provides an indication of where risk is concentrated, either practices or games.

Statistical Analyses

Statistical analyses included chi-squares, the IDR, and the percentages of injuries that were classified as a concussion. Iteration proportion fitting chi-squares were conducted to create theoretical expected values. Chi-squares were performed to analyze differences between years, practice versus games, and among sports. The 95% confidence intervals were calculated according to the methods of Miettinen (1973). The Statistical Package for the Social Sciences, version 10.1, was used for all statistical analyses. The statistical significance level was set at $p < .01$.

Results

For the 15 sports studied during the 3 academic years, the NCAA ISS documented 3,535 team-seasons, 40,547 reportable injuries, 5,566,924 practice AEs, and 1,090,298 game AEs. Overall, 6.2% of all injuries suffered by both men and women were concussions. Of the reported injuries, 1,224 (1,224/24,480 = 5.0%) concussions were sustained during practice and 1,278 (1,278/15,975 = 8.0%) were sustained during games. Female athletes sustained 191 (191/5,788 = 3.3%) concussions during practices and 331 (331/3,719 = 8.9%) concussions during games. Male athletes sustained 1,033 (1,033/18,782 = 5.5%) concussions during practices and 947 (947/12,299 = 7.7%) concussions during games. Data for practice and game concussions are shown in Tables 1 through 4.

Chi-square analysis revealed statistical significance between male games and male practice session for football ($\chi^2 = 734.9$), soccer ($\chi^2 = 323.1$), ice hockey ($\chi^2 = 141.7$), lacrosse ($\chi^2 = 82.3$), wrestling ($\chi^2 = 63.9$), baseball ($\chi^2 = 50.2$), and basketball ($\chi^2 = 24.7$; see Table 1). Chi-square analyses revealed statistical significance between female games and female practices for soccer ($\chi^2 = 478.83$), basketball ($\chi^2 = 45.33$), lacrosse ($\chi^2 = 23.74$), and field hockey ($\chi^2 = 8.11$; see Table 3). Results revealed the highest IDR for male games to practices were the 1999–2000 soccer (39.00), 1998–1999 lacrosse (22.57), 1997–1998 wrestling (18.10), and the 1997–1998 ice hockey (17.35) seasons (see Table 1). The highest IDR for female games to practices were the 1998–1999 (18.64), 1999–2000 (17.00), and 1997–1998 (14.57) soccer seasons and the 1998–1999 field hockey (10.5) season (see Table 3). Of all the reported male game injuries, the 1999–2000 lacrosse (11.9%) players suffered the highest percentage of concussions, followed by the 1999–2000 ice hockey (11.6%), 1997–1998 wrestling (10.9%), and 1997–1998 ice hockey (10.2%) seasons (see Table 1). Of all the reported male practice injuries, the 1997–1998 ice hockey (7.9%) players reported the highest percentage of concussions, followed by the 1998–1999 spring football (7.4%), 1999–2000 football (7.2%), and 1998–1999 football (6.7%), and 1999–2000 spring football (6.7%; see Table 2). The highest percentage of concussions reported for female games were the 1997–1998 lacrosse (16%), 1998–1999 lacrosse (13.5%), 1999–2000 lacrosse (12.1%), and 1999–2000 soccer seasons (12.1%; see Table 3). The highest percentage of concussions reported for female practice sessions were 1997–1998 lacrosse (8.9%), 1997–1998 field hockey (5.4%), 1999–2000 basketball (5.1%), and 1999–2000 softball (4.9%; see Table 4).

Table 1. *Male Game Concussions*

Sport	Year	Total Games	Total Number of Injuries	Total Concussions	Concussion Injury Rates[a]	Percentage of Concussions[b]	IDR[c]	Chi-Square[d]
Hockey	97–98	19,005	362	37	2.95	10.2%	17.35	141.7*
	98–99	14,080	239	20	1.42	8.4%	14.2	
	99–00	21,462	362	42	1.96	11.6%	15.08	
Lacrosse	97–98	13,486	213	19	1.41	8.9%	10.07	82.3*
	98–99	9,514	156	15	1.58	9.6%	22.57	
	99–00	12,177	143	17	1.39	11.9%	7.32	
Football	97–98	52,317	1,795	121*	2.32	6.7%	10.9	734.9*
	98–99	52,505	1,776	137*	2.61	7.7%	3.0	
	99–00	67,393	3,022	280*	4.15	9.3%	5.9	
Wrestling	97–98	10,422	311	34*	3.26	10.9%	18.1	63.9*
	98–98	5,169	132	4*	0.77	3.0%	2.2	
	99–00	9,807	305	18	1.84	5.9%	5.9	
Soccer	97–98	30,966	549	34	1.10	6.2%	13.75	323.1*
	98–99	19,142	376	27	1.41	7.2%	12.82	
	99–00	25,636	529	40	1.56	7.6%	39.00	
Basketball	97–98	27,706	220	8	0.29	3.6%	2.07	24.7*
	98–99	39,367	402	21	0.26	5.2%	1.37	
	99–00	32,836	327	20	0.61	6.1%	3.81	
Baseball	97–98	51,351	289	22	0.43	2.7%	5.38	50.2*
	98–99	49,207	293	6	0.12	2.0%	1.71	
	99–00	80,215	482	25	0.31	5.2%	7.75	
Gymnastics	97–98	277	1	0	0	0%	0	0
	98–99	221	0	0	0	0%	0	
	99–00	1,179	8	0	0	0%	0	

Note: IDR = Incidence Density Ratio.
[a]Total concussions divided by total athlete exposures. [b]Of all reported injuries, percentage of injuries that were concussions. [c]Ratio comparing games to practice-injury rates. [d]Chi-squares comparing games to practices.
*Statistically significant at $p = .01$.

Football

Data were collected in the sport of football for 361 teams (an average of 120 per year) during the 3-year period. Concussions accounted for 6.7% of all reported injuries during fall practice, 8.8% during football games, and 5.5% during spring football practices over the 3-year period. Players were found to have a 10 times (IDR 10.54) greater risk of suffering a concussion during football games than practices over the 3-year period. Results revealed that football players in the 1999–2000 season reported a significantly higher number of concussions than for the 1997–1998 ($\chi^2 = 36.20$) and 1998–1999 football seasons ($\chi^2 = 23.5$). Results also indicated a significantly higher number of concussions during the 1999–2000 practice season when compared to the 1997–1998 practice season ($\chi^2 = 16.25$). Interestingly, game injury rates almost doubled from the 1997–1998 (2.32) to the 1999–2000 football (4.15) seasons (see Table 1).

Ice Hockey

During the 3-year period, data for ice hockey were recorded for 95 teams (an average of 32 per year). One hundred and twenty-six players sustained a concussion during the 3-year study. Of all the injuries suffered by ice hockey players, concussions accounted for 6.3% of practice injuries and 10.3% of game injuries. Ice hockey players were found to be at a 15.5 times greater risk for suffering a concussion during games than during practice sessions.

Soccer

In men's soccer, 267 teams (an average of 89 per year) were analyzed during the 3-year period. One hundred and twenty-three concussions occurred during the 3 years, with game concussions accounting for 7.0% and practice concussions accounting for 1.7% of all the reported injuries. Male soccer players were at a

Table 2. *Male Practice Concussions*

Sport	Year	Total Practices	Total Number of Injuries	Total Concussions	Concussion Injury Rates[a]	Percentage of Concussions[b]
Football	97–98	637,698	2,415	145*	0.23	6.0%
	98–99	640,871	2,683	180	0.28	6.7%
	99–00	846,300	3,949	284*	0.34	7.2%
Hockey	97–98	69,795	152	12	0.17	7.9%
	98–99	52,369	108	5	0.1	4.6%
	99–00	78,757	172	10	0.13	5.8%
Spring	97–98	113,711	1,274	78	0.67	6.1%
Football	98–99	50,619	529	39	0.77	7.4%
	99–00	83,213	1,004	67	0.66	6.7%
Wrestling	97–98	92,782	661	17	0.18	2.6%
	98–98	51,381	323	20	0.35	6.2%
	99–00	83,213	604	28	0.31	4.6%
Basketball	97–98	118,905	424	16	0.14	3.8%
	98–99	164,607	693	31	0.19	4.5%
	99–00	140,637	569	22	0.16	3.9%
Lacrosse	97–98	76,246	282	11	0.14	3.9%
	98–99	56,201	215	4	0.07	1.9%
	99–00	74,115	223	14	0.19	6.3%
Baseball	97–98	127,623	316	10	0.08	3.2%
	98–99	130,988	284	9	0.07	3.2%
	99–00	213,674	413	9	0.04	2.2%
Soccer	97–98	127,013	535	10	0.08	1.9%
	98–99	77,769	369	8	0.11	2.2%
	99–00	106,241	440	4	0.04	0.9%
Gymnastics	97–98	3,897	5	0	0	0%
	98–99	3,265	7	0	0	0%
	99–00	9,867	60	0	0	0%

[a]Total concussions divided by athlete exposures. [b]Of all reported injuries, percentage of injuries that were concussions.
*Statistically significant at $p = .01$.

21.9 times greater risk of suffering a concussion during games than practices. Male soccer players' IDR tripled from the 1998–1999 (12.82) season to the 1999–2000 season (39.00).

Data were collected in the sport of women's soccer for 288 teams (an average of 96 per year) during the 3-year period. One hundred and ninety-two concussions were reported during the 3 years. The IDR was 16.7 times higher for games than practice sessions. Of all the injuries suffered by female soccer players, concussions accounted for 11.4% for games and 2.4% for practice.

Lacrosse

One hundred and nineteen teams were analyzed in men's lacrosse (an average of 40 per year) during the 3-year period. Eighty concussions were reported during the 3-year study. Of all injuries sustained during men's lacrosse, 4.0% represented practice concussions and 10.1% represented game concussions. Injury rates for concussions in games were 13.32 times higher than practice sessions.

Women's lacrosse reported data on 112 teams (an average of 37 per year) during the 3-year period. Of all injuries sustained during women's lacrosse, 5.3% represented practice concussions and 13.9% represented game concussions. The IDR was 6.3 times higher during games than practices.

Wrestling

Results revealed that, out of 143 wrestling teams (an average of 47 per year), 121 concussions were sustained over the 3 years. The IDR was 8.7 over the 3 years. However, the IDR was 18.1 for the 1997–1998 season and then dropped significantly to 2.2 in the next season ($\chi^2 = 12.64$). Concussions account for 6.6% during matches and 4.5% during practices.

Table 3. *Female Game Concussions*

Sport	Year	Total Games	Total Number of Injuries	Total Concussions	Concussion Injury Rates[a]	Percentage of Concussions[b]	IDR[c]	Chi-Square[d]
Lacrosse	97–98	8,762	75	12	1.37	16.0%	3.26	23.74*
	98–99	7,122	52	7	0.98	13.5%	9.80	
	99–00	8,531	58	7	0.82	12.1%	5.86	
Soccer	97–98	24,981	454	51	2.04	11.2%	14.57	478.83*
	98–99	22,934	430	47	2.05	10.9%	18.64	
	99–00	27,167	497	60	2.21	12.1%	17.00	
Basketball	97–98	29,413	233	16	0.54	6.9%	2.35	45.33*
	98–99	38,174	349	30	0.78	8.6%	4.11	
	99–00	28,992	262	26	0.89	9.9%	3.87	
Softball	97–98	26,834	143	9	0.34	6.3%	2.27	0.24
	98–98	44,280	197	10	0.23	5.1%	2.56	
	99–00	75,355	365	28	0.37	7.7%	2.64	
Field	97–98	11,065	78	3	0.27	3.8%	1.59	8.11*
Hockey	98–99	4,770	43	5	1.05	11.6%	10.5	
	99–00	11,278	65	4	0.35	6.2%	7.00	
Volleyball	97–98	24,904	124	5	0.2	4.0%	4.00	6.05
	98–99	24,482	90	4	0.16	4.4%	8.00	
	99–00	35,203	151	6	0.17	3.9%	1.89	
Gymnastics	97–98	8,903	34	1	0.11	0.3%	0.84	0.002
	98–99	822	12	0	0	0%	0	
	99–00	2,083	23	0	0	0%	0	

Note: IDR = Incidence Density Ratio.
[a]Total concussions divided by total athlete exposures. [b]Of all reported injuries, percentage of injuries that were concussions. [c]Ratio comparing games to practice injury rates. [d]Chi-squares comparing games to practices.
*Statistically significant at $p = .01$.

Table 4. *Female Practice Concussions*

Sport	Year	Total Practices	Total Number of Injuries	Total Concussions	Concussion Injury Rates[a]	Percentage of Concussions[b]
Lacrosse	97–98	33,342	158	14	0.42	8.9%
	98–99	31,048	82	3	0.1	3.6%
	99–00	37,765	149	5	0.14	3.4%
Basketball	97–98	104,872	497	24	0.23	4.8%
	98–98	140,817	617	26	0.19	4.2%
	99–00	108,480	495	25	0.23	5.1%
Softball	97–98	45,291	165	7	0.15	4.2%
	98–99	76,076	229	7	0.09	3.1%
	99–00	129,155	345	17	0.14	4.9%
Field	97–98	41,340	130	7	0.17	5.4%
Hockey	98–99	19,398	59	2	0.1	3.4%
	99–00	42,016	138	3	0.05	2.2%
Soccer	97–98	87,442	457	12	0.14	2.6%
	98–99	77,286	472	9	0.11	1.9%
	99–00	100,855	507	13	0.13	2.6%
Volleyball	97–98	60,179	203	3	0.05	1.5%
	98–99	31,130	337	1	0.02	0.3%
	99–00	88,875	369	8	0.09	2.2%
Gymnastics	97–98	31,006	224	4	0.13	1.8%
	98–99	9,253	45	0	0	0%
	99–00	19,829	136	1	0.05	0.7%

[a]Total concussions divided by total athlete exposures. [b]Of all reported injuries, percentage of injuries that were concussions.

Basketball

Men's basketball reported data on 372 teams (an average of 124 per year) during the 3-year period. One hundred and eighteen athletes suffered a concussion, with concussions accounting for 4.1% of all the injuries sustained during practices and 5.0% during games. Results indicated game injury rates doubled from the 1997–1998 season (0.29) to 1999–2000 season (0.61). However, injury rates were not significant over the 3 years.

Women's basketball reported data on 376 teams (an average of 125 per year) during the 3-year period. Female basketball players suffered a total of 147 concussions. Concussions accounted for 4.7% of all the injuries sustained during practices and 8.5% during games. Women basketball players are at a 3.4 times higher risk of suffering a concussion during a game situation than a practice session. Results revealed a gradual increase in game injury rates from the 1997–1998 season (0.54) to the 1999–2000 season (0.89).

Field Hockey

Data were collected in women's field hockey for 104 teams (an average of 35 per year) during the 3-year period. Twenty-four concussions were reported over the 3-year period, with an IDR of 6.4. Concussions accounted for 3.7% of all injuries suffered during practices and 7.2% during games.

Softball

Data were collected in the sport of softball for 331 teams (an average of 110 per year) during the 3-year period. IDR was 2.5 times greater for softball games than for practices. A total of 78 concussions were reported during the 3-year study. Practice concussions accounted for 4.1% of all injuries, while game concussions accounted for 6.4% of all injuries.

Baseball

Baseball reported 337 teams (an average of 112 per year) with an IDR 3.8 times greater for games than practices. Eighty-one concussions were reported during the 3-year study. Results found 2.9% of all practice injuries were concussions and 4.2% of all game injuries were concussions.

Volleyball

Data were analyzed in volleyball for 304 teams (an average of 101 per year) during the 3-year period. Twenty-seven concussions were reported for the 3-year study. Of all the injuries reported, concussions accounted for 1.3% during practices and 4.1% during games. Volleyball players are at a 3.8 times greater risk of sustaining a concussion during a game situation than a practice session.

Gymnastics

Data were collected in the sport of women's gymnastics for 49 teams (an average of 16 per year) during the 3-year period. Women's gymnastics reported four practice concussions during the 1997–1998 season and one concussion during the 1999–2000 season. Only one competition concussion was reported during the 1997–1998 season, with no other concussions reported for the next 2 years. Results revealed no concussions were sustained in men's gymnastics for 12 teams (an average of 4 per year) during the 3-year period.

Discussion

The purpose of this study was to examine the incidence and prevalence of concussions among 15 different intercollegiate sports during the 1997–1998 season to the 1999–2000 season. During this 3-year study, concussions accounted for 6.2% of all reported injuries. Powell and Barber-Foss (1999) reported that mild traumatic brain injury accounted for 3.9% of all injuries suffered in 10 high school sports. The differences found in our study may be attributed to sample population (high school versus college), grading scale of concussions, and the design of the study. Furthermore, our study included ice hockey, women's and men's lacrosse, and spring football, which may have contributed to the higher concussion rate.

The differences in concussion rates in all male sports except gymnastics were found to be significant between games and practices, whereas female soccer, basketball, lacrosse, and field hockey were also found to be significant between games and practices. Female athletes from all seven sports were found to be at a lower risk for suffering concussions during practice sessions than the eight male sports. However, women were found to be at a greater risk for suffering concussions during games than men. Further research is

needed to determine why women are suffering a greater number of concussions during games but not practices. One possible explanation is female athletes may be practicing at a lower intensity level relative to their game level intensity than male athletes. Alternatively, there may be neuropsychological differences in the susceptibility to concussions among women.

Concussions in Football Players

Of all the sports, football was found to have the highest number of concussions suffered during both practices and games. Our results indicate 8.8% of all football players are at risk for sustaining a concussion during games. This is in agreement with Barth et al. (1989), who indicated 7.7% were, and McCrea et al. (1998), who reported that 5.8% of all football injuries are concussions during a single season.

Athletes at Risk for Suffering a Concussion

Athletes at the highest risk for suffering a concussion are those participating in football, ice hockey, wrestling, men's and women's soccer, and men's and women's lacrosse. A possible explanation may be the nature of each sport. For example, football and ice hockey are considered contact sports in which contact is an expected and often desirable part of the game. Although soccer and women's lacrosse do not involve intentional collisions between players, incidental collisions frequently occur as a result of heading. Given the current findings, it appears important that researchers continue to track these athletes and develop strategies to reduce the number of concussions sustained yearly.

Athletes who participate in men's and women's gymnastics, baseball, softball, and volleyball are at the lowest risk for suffering a concussion. A possible explanation may be the safety standards or the low risk of contact. Gymnastics is considered a high-risk sport but not for concussions. Gymnasts land on soft mats or into foam pits, which cushion the blow or force to the head. Baseball and softball players wear a helmet to protect them from head injuries. Volleyball players rarely make head-to-head contact with each other or the floor.

Concussions in Male Athletes

Of all the male sports, ice hockey players suffered the greatest percentage of concussions during game situations (10.3%). These results contradicted Tegner and Lorentzon (1996), who reported 6.5% of elite hockey players sustained a concussion during league play and concluded that 20% of elite ice hockey players will endure one concussion during their career. When you consider injury rates, football players suffered the greatest number of concussions in relation to AEs. Furthermore, football was the only sport to report statistical significance between years. Football players during the 1999–2000 season reported a significantly higher number of concussions during games compared to the 1997–1998 and 1998–1999 seasons. Football players also experienced a significantly greater number of concussions during the 1999–2000 practice season than the 1997–1998 practice season.

Concussions in Female Athletes

Women's soccer was found to have the highest injury rate and IDR among all women's sports. Although women's lacrosse was found to have the highest inherent risk of sustaining a concussion during a game situation (13.9%), female lacrosse players sustain very few injuries compared to other female sports. This would suggest that female lacrosse is a relatively safe sport; however, the percentage of injuries classified as concussions is considerably higher than in other female sports. Recently, there has been considerable debate among coaches and safety committees as to whether helmets should be worn to protect lacrosse players from head injuries (Brown, 2001). Brown (2001) argued that if female lacrosse players wear safety equipment, athletes will become more aggressive, making the game more dangerous.

Reporting Concussions

High-profile concussions focus on professional hockey and football players. Recently, the NHL and National Football League implemented baseline neuropsychological assessment of all players (Lovell & Collins, 1998). Once an athlete has sustained a concussion, he or she completes the neuropsychological test battery at the following postinjury intervals: 24 hr, 5 days, and 10 days (Macciocchi, Barth, Alves, Rimel, & Jane, 1996). To help evaluate cognitive deficits, neuropsychological baseline tests should be implemented in middle school, high school, and collegiate athletes, especially for football and ice hockey players. Furthermore, epidemiological studies should be conducted on

middle school and high school athletes to determine injury rates on concussions. Recently, researchers are becoming more effective in reporting IDRs; however, there still remains work to be done with classifying athletes with concussions and implementing a screening maintenance plan.

Limitations of This Study

There are several limitations to this study. First, there is no common definition, grading scale, or measure of severity of concussions for the NCAA ISS. As a result, what one athletic trainer or physician may report as a Grade 1 concussion may be classified by another healthcare provider as a Grade 2 concussion. However, it should be noted that all grades of concussions in this study were represented in the overall percentages of concussions sustained by athletes.

Another limitation to this study is the evaluation of AEs. The NCAA ISS reports an AE as an athlete participating in one game or practice where she or he is exposed to the possibility of athletic injury. However, an athlete who plays a 45-sec hockey shift during a game is reported as participating in one game. Another hockey player who played 21 min of the game is also represented as exposed to one game. As a result, time played is not considered in the definition of AE.

Conclusion

Concussions accounted for 6.2% of all reported injuries during this 3-year study. Female athletes from all seven sports were found to be at a lower risk for suffering concussions during practice sessions than the eight male sports. However, female athletes were found to be at a greater risk for suffering concussions during games than male athletes. Concussions continue to be on the rise for football players, whereas those participating in ice hockey, men's and women's lacrosse, men's and women's soccer, women's basketball, and wrestling are all at risk for suffering a concussion.

Future research is needed to establish yearly injury trends to determine which athletes are at a greater risk for acquiring a concussion. Research is also needed to evaluate and implement strategies to reduce the number of concussions sustained yearly by collegiate, high school, and middle school athletes. Further empirical studies are needed to establish baseline neuropsychological assessments for all collegiate, high school, and middle school sports to help aid in the return to play criteria.

This article reviewed important epidemiological characteristics of college athletes. Neuropsychologists who are practicing in this area should familiarize themselves with these data to understand the base rates for concussions in the sport that they may be assisting with. Trends over time and gender differences are important aspects of the landscape of concussions of athletes. Neuropsychologists should understand the complexity of concussion rates in intercollegiate athletics in order to become informed and competent consultants when dealing with a college student population.

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